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High-power, wavelength-tunable UV picosecond laser pulses can be generated by normal, angle-tuned, extra-cavity frequency doubling. Conversion efficiences of 1 to 7% can be obtained by careful adjustment of the dye laser cavity length.

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Efficient Frequency Doubling for Synchronously Mode-Locked Dye Lasers

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INTRODUCTION

Generation of high-power, wavelength-tunable UV picosecond laser pulses is commonly believed to require the use of pulse compression and cavity dumping[1] or the use of second harmonic generation in either an intracavity geometry[2] or an external-ring resonator.[3] These approaches use either high peak power or high circulating power to increase the generated UV. However, the addition of a pulse compressor increases the laser linewidth, while the use of a cavity dumper reduces the repetition rate of the laser. Both increase the cost and complexity of the laser system. Intracavity frequency doubling requires modification of the dye laser optics, which slaves the dye laser to UV operation and makes scanning the wavelength difficult. Moreover, the majority of such intracavity designs utilize ring dye lasers, which are more difficult to maintain in proper alignment than are standing-wave dye lasers. External ring resonators require additional optical components and critical matching of the two cavity frequencies. In comparison, we have found that normal, angle-tuned, extra-cavity frequency doubling can produce conversion efficiencies from 1 to 7% by careful adjustment of the dye laser cavity length.

INSTRUMENTATION

Tunable visible radiation is provided by a rhodamine 6G dye laser (Spectra-Physics Model 575B) that is synchronously pumped by a mode-locked, frequency-doubled Nd:YAG laser (Spectra-Physics Series 3000) operating at 82 MHz. The output of the dye laser passes through a focusing lens, a $LiIO_3$ crystal, a collimating lens, and a Pellin-Broca prism. The UV power is monitored with a pyroelectric radiometer (Laser Precision Corp., Model RkP 545). The 10 × 10 × 2-mm $LiIO_3$ crystal, cut at an angle of 60°, is encased in a cell with AR-coated windows. The crystal and cell, which is filled with index-matching fluid, are obtained from Quantum Technology Inc., Sanford, FL. A combination of translation and rotation stages allows positioning of the crystal to maximize the UV output.

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RESULTS AND DISCUSSION

Previous instrument development studies in pump/probe spectroscopy[5,6] have led us to the realization that dye laser cavity length is a critical parameter in determining signal quality. While attempting to produce high average power UV, we found that maximum conversion efficiency to the second harmonic also depends strongly on cavity length. For both characteristics, minimizing the autocorrelator pulse width does not locate the proper position. The optimum length for frequency doubling is from 2 to 12 μm longer than that producing the shortest pulses, depending upon the number of elements in the Lyot filter. The length adjustment has to be made very carefully since minor changes have a pronounced effect on the UV power produced for a given fundamental power. For example, a 2-μm change from the optimum cavity length yields a 27% drop in UV power.

Using 3.0-ps pulses at 600 nm and an average fundamental power of 390 mW passing through a 160-mm-focal-length lens, 12 mW of average UV power was produced at 300 nm. The power could be increased to 28 mW with the use of a 120-mm-focal-length lens, but the UV power dropped and then stabilized at 19 mW over a ten-minute period. This results in a maximum conversion efficiency of between 3 and 7%. These values compare very favorably with a reported conversion efficiency of 9 × 10⁻³% for intra-cavity doubling of a continuously mode-locked laser[2] and 15% for extra-cavity doubling of a cavity-dumped, sub-picosecond laser.[4] At the edges of the dye tuning curve, the conversion efficiency remained higher than 1%. As an example, at 635 nm the average fundamental power dropped to 185 mW but still produced 2.1 mW of average UV power at 317.5 nm.

This observation is not an isolated event unique to the laser or doubling crystal. Comparable results have been independently reproduced on other laser systems with different $LiIO_3$ crystals. The optical scheme for producing high-power, high-repetition-rate picosecond UV pulses is simple, and the conversion efficiencies obtained are substantially higher than any previously reported for continuously mode-locked dye lasers. As noted previously, the precise cavity length for maximum conversion efficiency is difficult to locate with the use of an autocorrelator. Monitoring UV power is the best method for fine cavity length adjustment.

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